### Objective of Presentation

- Review disease specific ventilator strategies
- Discuss non-invasive approaches to improving gas exchange
- Review graphical analysis of mechanical ventilation

### Two Primary Types of Ventilation

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure limited</td>
<td>Cycled by time or flow, variable flow to meet patient demand</td>
<td>Constant pressure, better tolerated-decelerating inspiratory flow rate</td>
<td>VT variable and depends on the patient’s lung mechanics</td>
</tr>
<tr>
<td>Pressure limited - TCPL</td>
<td>Cycled by time or flow, variable flow to meet patient demand</td>
<td>Constant pressure, better tolerated-decelerating inspiratory flow rate</td>
<td>VT variable and depends on the patient’s lung mechanics</td>
</tr>
<tr>
<td>Pressure limited - PC</td>
<td>Cycled by time or flow, variable flow to meet patient demand</td>
<td>Constant pressure, better tolerated-decelerating inspiratory flow rate</td>
<td>VT variable and depends on the patient’s lung mechanics</td>
</tr>
<tr>
<td>Pressure limited - PSV</td>
<td>Cycled by time or flow, variable flow to meet patient demand</td>
<td>Constant pressure, better tolerated-decelerating inspiratory flow rate</td>
<td>VT variable and depends on the patient’s lung mechanics</td>
</tr>
<tr>
<td>Pressure limited - VC</td>
<td>Cycled by time or flow, variable flow to meet patient demand</td>
<td>Constant pressure, better tolerated-decelerating inspiratory flow rate</td>
<td>VT variable and depends on the patient’s lung mechanics</td>
</tr>
<tr>
<td>Volume limited - VC</td>
<td>Cycled by time or flow, variable flow to meet patient demand</td>
<td>Guaranteed tidal volume, better control of ventilation due to stable minute</td>
<td>Set flow rate may not match patient’s demand*, Increased muscle workload from</td>
</tr>
<tr>
<td>Volume limited - VG</td>
<td>Cycled by time or flow, variable flow to meet patient demand</td>
<td>Guaranteed tidal volume, better control of ventilation due to stable minute</td>
<td>ASynchrony, may compromise comfort</td>
</tr>
</tbody>
</table>
Conventional Ventilation Part II

Modes of Ventilation

- Controlled Mechanical Ventilation (CMV)
- Assist/Control (AC)
- Synchronized Intermittent Mandatory Ventilation (SIMV)
- Pressure Support Ventilation (PSV)*
- Continuous Positive Airway Pressure (CPAP)
- Airway Pressure Release Ventilation (APRV)
- Neutrally Adjusted Ventilatory Assist (NAVA)
- Proportional Assist Ventilation (PAV)
- Volume Assure Pressure Support (AVAPS)

Modes of Ventilation

Assist-Control (AC)

- The desired minute ventilation (rate x VT or PIP) is set.
- The patient can increase their minute ventilation by triggering patient initiated machine breath.
- Less frequently used mode in the neonate population compared to SIMV and CPAP
  - Idiopathic refractory apnea of prematurity
  - Coma
  - Intracranial bleed - maintain Intracranial pressure (ICP)
  - Patients on neuromuscular blocking agent

Modes of Ventilation

Synchronized Intermittent Mandatory Ventilation (SIMV)

- Preferred mode among infants and pediatric population.
  Pt is able to increase their minute ventilation above the set minute ventilation (Rate x VT or PIP) by spontaneous breathing.
- Better patient – ventilator synchrony
- Lower mean airway pressures
- Provided better neurological assessment of the developing infant
- Preservation of respiratory muscle function
**Continuous Positive Airway Pressure (CPAP)**

- Mostly used with non-invasive positive pressure ventilation
- Weaning mode - does not provide full ventilatory support
- Patient has to be spontaneously breathing and initiate all breath
- Primarily used for improving oxygenation
- Increases FRC and decreases WOB
- Primary control is PEEP
- Most CPAP modes do not have back up apnea ventilation

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**Neurally Adjusted Ventilatory Assist (NAVA)**

**CV breath sequence**
1. CNS
2. Phrenic nerve
3. Diaphragm excited
4. Diaphragm contracts
5. Chest wall and lungs expand
6. Airway pressure change
7. Ventilator senses change
8. Ventilator delivers a breath

**NAVA breath sequence**
1. CNS
2. Phrenic nerve
3. Diaphragm excited
4. Ventilator delivers a breath

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Courtesy MAQUET Medical
NAVA - Electrical Diaphragm (Edi) catheter

Edi Catheter Functionality
- Special Edi Catheter is placed (Electronic Diaphragm Monitoring)
- Can replace your OG/NG tubes
- Has 10 electrodes, 9 of which are used to read the electrical activity of the diaphragm
- Searches for changes in electrical activity 62.5 times per second
- Follow your units Clinical Standards for OG/NG maintenance.
- Yes, you can feed and give meds through this catheter
- Yes, you can use this catheter for low intermittent suction
- The Edi Catheter needs to be changed every 5 days

Neurally Adjusted Ventilatory Assist (NAVA)
- Similar to PAV but sensing at diaphragm
- NAVA looks at EMG
- Does not force a ventilator pattern
- Neural Respiration
Edi Catheter Waveform

Positioning window
The Edi catheter is correct positioned if the second and third leads are highlighted in pink/blue and the Edi signal is present.

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**Modes of Ventilation (con’t)**

**Benefits of NAVA**
- Invasive and non-invasive
- Eliminates patient-ventilator asynchrony
- Not effected by auto PEEP, or any ineffective trigger mechanism
- Captures diaphragm EMG - Used as a tool to adjust ventilator pressure support
- Increase patient comfort
- Promotes spontaneous breathing

**Disadvantages of NAVA**
- Cost of catheter
- Incorrect insertion technique
- Catheter only available for Patients greater than 500 grams

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**Modes of Ventilation (con’t)**

**AIRWAY PRESSURE RELEASE VENTILATION (APRV)**

- Spontaneously breathing patients - CPAP with intermittent release in pressure
- Full support/ Apenic patients - Pressure control with inverse ratio ventilation
- Used mostly on ALI/ARDS patients
- Primary goal - Oxygenation
  - Sustained airway pressure → lung recruitment
- Secondary goal - Ventilation
  - Pressure gradient difference determines the VT
  - The rate (release) per min
  - Patient’s spontaneous breathing
Modes of Ventilation (con’t)

**TYPE: APRV/Bi-LEVEL**
- Same concept but terminology and setting vary slightly based on type of ventilator
  - Carefusion AVEA - APRV¹
  - PB 840 - BiLevel²
  - Servo i - Bi Vent³
- PS setting is also different based on the ventilator

**Four commonly used terms:**
- Pressure high: $P_{high}$ / PEEP H¹ / $P_{high}$³
- Time high: $T_{high}$ / T H² / $T_{high}$³
- Pressure low: $P_{low}$ / PEEP I / PEEP²
- Time low: $T_{low}$ / T PEEP / $T_{low}$³

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**APRV Ventilation - AVEA**

P LOW is set at 0

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**Modes of Ventilation (con’t)**

**BENEFITS OF APRV:**
- Improves oxygenation by increasing MAP
- Decreases VILI
- Decrease oxygen toxicity
- Improves V/Q matching
- Decreased need for sedation / NMB
- Facilitates spontaneous breathing
- Improves hemodynamic profile
Modes of Ventilation (con’t)

DISADVANTAGES OF APRV:
• Variable tidal volume ($V_T$)
  • $V_T$ affected by compliance and resistance
• Patient–ventilator dysynchrony
  • Non sedated, spontaneously breathing patient
• Adequate spontaneous ventilation is necessary to augment CO₂ removal
• Risk for Auto-PEEP
• Improvement in oxygenation is seen after several hours

ABG indication of respiratory failure

<table>
<thead>
<tr>
<th>Infants</th>
<th>Pediatric</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH &lt; 7.20</td>
<td>pH &lt; 7.30</td>
</tr>
<tr>
<td>PaCO₂ &gt;60 mmHg</td>
<td>PaCO₂ &gt;50 mmHg</td>
</tr>
<tr>
<td>PaO₂ &lt; 50 mmHg</td>
<td>PaO₂ &lt; 70 mmHg</td>
</tr>
<tr>
<td>SaO₂ &lt; 88%</td>
<td>SaO₂ &lt; 88%</td>
</tr>
<tr>
<td>(on FiO₂ &gt; 0.60)</td>
<td>(on FiO₂ &gt; 0.60)</td>
</tr>
<tr>
<td>SpO₂ &gt; 88%</td>
<td>SpO₂ &gt; 88%</td>
</tr>
</tbody>
</table>

Key Factors for Initial Ventilator Setting

1- Age and Weight of patient
  • Pre-term→Full Term→Pediatric
  • Estimate initial tidal volume ($V_T$)
2- Level of Consciousness
  • Full support / Partial Support
3- Diagnosis and Clinical Condition
  • Volume Ventilation - Pediatric/Adult
  • Pressure Ventilation - Neonate Population
4- Severity and Prognosis of the Clinical Condition
  • Conventional Mode VS Advanced Mode
  • Conventional Ventilator VS High Frequency Ventilation
**Initial Ventilator Parameters**

<table>
<thead>
<tr>
<th>Infants</th>
<th>Pediatric</th>
</tr>
</thead>
<tbody>
<tr>
<td>VT: 4-6 ml/kg</td>
<td>VT: 6-10 ml/kg</td>
</tr>
<tr>
<td>RR: 20-40 bpm</td>
<td>RR: 12-25 bpm</td>
</tr>
<tr>
<td>PEEP: 2-3 cmH2O</td>
<td>PEEP: 2-3 cmH2O</td>
</tr>
<tr>
<td>PIP: &lt; 30 cmH2O</td>
<td>PIP: &lt; 35 cmH2O</td>
</tr>
<tr>
<td>Flow: 6-10 L/min</td>
<td>Flow: 8-15 L/min</td>
</tr>
<tr>
<td>FiO2: &lt; 0.60</td>
<td>FiO2: &lt; 0.60</td>
</tr>
<tr>
<td>IT: 0.25 - 0.5</td>
<td>IT: 0.6 - 0.8</td>
</tr>
</tbody>
</table>

**Weaning Criteria**

- The primary reason for initiating mechanical ventilation has been reversed or is resolving
- The ABG is within the normal range
  - pH: 35-45
  - PaCO2: 35-45 mmHg
  - PaO2: 60-80 mmHg
  - SaO2: > 90%
  - FiO2: ≤ 0.40
  - PEEP: ≤ 5 cmH2O

**Weaning Criteria**

- Negative Inspiratory Force (NIF) > 20 cmH2O
- Vital capacity > 10 mL/kg
- Rapid shallow breathing index (RSBI) < 105
- PaO2/FiO2 ratio (PF/Ratio) > 300
- Positive leak test around the artificial airway
  - Indicates status of any airway edema
Disease Specific Ventilation Strategy

Low pressure or high pressure ventilation strategies are used both on a conventional ventilator and high frequency ventilator based on the pathophysiology of the disease.

Goal = Maintain adequate oxygenation and ventilation at the lowest pressure to prevent VILI/VALI

Any change in inspiratory pressure (IP) \( \rightarrow \) change in tidal volume \( (V_T) \) \( \rightarrow \) change in ventilation \( \rightarrow \) change in PaCO2

Disease Specific Ventilation Strategy (cont)

Low pressure ventilation (< 30 cmH20) used on patients with the following disease process:
- MAS
- Pneumothorax
- PIE
- CDH

High pressure ventilation (< 35 cmH20) used on patients with the following disease process:
- RDS
- Cystic Fibrosis

Complications of Mechanical Ventilation

- Ventilator Associated Pneumonia (VAP) in Pediatric
- Oxygen toxicity
- Cardiovascular effects
- VILI – ventilator induced lung injury
  - Volutrauma - damage to alveoli due to over distension
  - Barotrauma- damage to alveoli due to excessive pressure
  - Atelectrauma - damage to alveoli due to the repetitive closing and requiring higher pressures in order to re-open
  - Biotrauma - damage to alveoli caused by certain pro inflammatory mediator cell released due to overstretching of the alveoli
**Disease Specific Ventilation Strategy**

**REVIEW QUESTIONS:**

A 1800g pre term infant is intubated and placed on a CV for surfactant administration therapy. What initial setting would be appropriate for this infant.

a) A/C - PIP:20, IT:0.6, Rate: 20, Flow 12Lpm, PEEP 3  
b) A/C - PIP:35, IT:0.4, Rate: 30, Flow 10Lpm, PEEP 5  
c) SIMV- PIP:20, IT:0.4, Rate: 30, Flow 7Lpm, PEEP 3  
d) SIMV-PIP:25, IT:0.3, Rate: 35, Flow 9LPM, PEEP 5

**REVIEW QUESTIONS (CON’T)**

A two month infant weighs 3600g is placed on a TCPL ventilator. The target V\textsubscript{T} is 6ml/kg. Based on the ABG and vent setting what parameter changes should be made to better ventilate the infant.

**Vent:** PIP 30, PEEP 8, I time 0.6, Rate: 35, FiO\textsubscript{2} 0.70, Flow: 10 lpm, Vte 4ml/kg  
**ABG:** pH: 7.27, PaCO\textsubscript{2}: 72, PaO\textsubscript{2}: 77, HCO\textsubscript{3}: 23, BE:2.1, SaO\textsubscript{2}: 86%  
a) Increase the PIP  
b) Increase the Rate  
c) Decrease the PEEP  
d) Decrease the PIP

**REVIEW QUESTIONS (CON’T):**

Based on the second ABG what parameter change should be made to better ventilate the infant  
**Vent:** PIP 35, PEEP 8, I time 0.6, Rate: 35, FiO\textsubscript{2} 0.60, Flow: 10Lpm, Vte 7ml/kg  
**ABG:** pH: 7.32, PaCO\textsubscript{2}: 67, PaO\textsubscript{2}: 77, HCO\textsubscript{3}: 21, BE= 1.9, SaO\textsubscript{2}: 86%  
a) Increase the PIP  
b) Increase the Rate  
c) Decrease the PEEP  
d) Decrease the PIP
An Infant with intracranial hemorrhage is being mechanically ventilated. The last ICP reading was 25 mmHg. The goal is to maintain the ICP < 20mmHg. Which ventilator change is best suited to accomplish this goal.

Current vent settings:
- PIP: 25
- PEEP: 4
- I time: 0.6
- Rate: 30
- FiO²: 0.60
- Flow: 8Lpm

ABG: pH: 7.35; PaCO₂: 40; PaO₂: 77; HCO₃: 23; BE: -1; SaO₂: 91%

a) Increase the PIP
b) Increase the FiO²
c) Increase the Rate
d) Decrease the PEEP

A term infant with MAS is placed on mechanical ventilation. The first year resident places the infant on the following settings and asks your opinion regarding the change.

Vent setting:
- SIMV- PIP 26, PEEP 3, I Time 0.8, Rate 35, FiO₂ 0.50, Flow 8Lpm

What change would you recommend?

a) SIMV- PIP 22, PEEP 5, I Time 0.4, Rate 30, FiO₂ 0.50, Flow 8Lpm
b) SIMV- PIP 18, PEEP 3, I Time 0.5, Rate 25, FiO₂ 0.70, Flow 8Lpm
c) SIMV- PIP 30, PEEP 5, I Time 0.6, Rate 30, FiO₂ 0.50, Flow 8Lpm
d) SIMV- PIP 30, PEEP 5, I Time 0.8, Rate 20, FiO₂ 1.0, Flow 8Lpm

Which would be the appropriate initial setting a premature infant with a LS ratio < 2:1?

a. PIP 16 , IT 0.5, Flow 10 Lpm, PEEP 15, Rate 30
b. PIP 25 , IT 0.6, Flow 18 Lpm, PEEP 0, Rate 35
c. PIP 32 , IT 1.0, Flow 8 Lpm, PEEP 5, Rate 25
d. PIP 20 , IT 0.4, Flow 6 Lpm, PEEP 3, Rate 30
A patient with copious secretion is intubated and placed on mechanical ventilation. The ideal humidifier would be:

a. A hygroscopic condenser humidifier
b. Heated wick humidifier
c. Cascade humidifier
d. Bubble humidifier

A 2 year old patient underwent a surgical procedure to correct an Atrial Septal Defect. He is receiving TCPL mechanical ventilation with a PIP of 19cmH2O, RR of 21, PEEP of 5cmH2O and FiO2 of 0.30. ABG results are as follows:

pH = 7.38, PaCO2 = 41mmHg, PaO2 = 52mmHg, HCO3 = 27mmHg.

You would now recommend:

a. Decrease the PIP
b. Increase the PIP
c. Increase the PEEP
d. Increase the FiO2

A pre term infant is placed on CPAP generator for treatment of atelactasis with mild hypoxemia. The initial CPAP level is 5 cmH2O. After placing the infant on the system the RT notices the measured CPAP pressure decreases to 3 cmH2O with each inspiration. What should the RT do to correct this problem?

a. Sedate the patient
b. Increase the CPAP level to 7cmH2O to compensate for the difference
c. Increase the flow
d. It is normal, once the infant settles down the pressure will be stabilized
Non-Invasive Positive Pressure Ventilation (NPPV)

NPPV refers to positive pressure ventilation delivered via a non invasive route (nasal prongs, nasal mask, face mask)

Indications:
- For spontaneously breathing patient who do not require emergency intubation and have a disease process that responds to NPPV
- Short term ventilation to improve oxygenation and decrease work of breathing

Non-Invasive Positive Pressure Ventilation (NPPV)

Helpful in preventing post extubation respiratory failure
- Increase FRC in infants
- Prevent atelectasis and decrease intrapulmonary shunting
- Grunting, retractions, nasal flaring
- Apnea and bradycardia of prematurity

References

Non-Invasive Positive Pressure Ventilation (NPPV)

Complications/ hazards associated with NPPV:
- Localized skin, nasal septal breakdown and necrosis
- Leak due to incorrect prong/mask size
- Eye irritation
- Mild gastric distention
- Obstruction of the nasal prongs from mucus plugging
- Complete obstruction of the prongs can result in false pressurization of the system without any alarm activation
- Pneumothorax
- Increased intracranial pressures

Non-Invasive Positive Pressure Ventilation (NPPV)

Benefits of using NPPV:
- Reduce the need for invasive mechanical ventilation
- Decrease the incidence of Chronic Lung Disease (CLD)
- Minimize barotrauma and volutrauma
- Low risk of infection compared to invasive ventilation
- Better access for oral care and promotes infants natural feeding cue and instincts
- Enhances communication patient and caregiver

Non-Invasive Positive Pressure Ventilation (NPPV)

TYPES OF INTERFACE
- Nasal prongs - most commonly used in the neonate population. They are obligate nose breathers. It very important to determine the correct prong size.
  - INCA® Infant Nasal CPAP prongs
- Nasal mask - used in infants with nasal septum breakdown or in low birth weight infants. Associated with less WOB compared to prongs
  - EME Medical® Nasal Mask
- Face mask - common used among pediatric population.
  - Philips Respironics®
- Nasal cannula – new upcoming trend. Easier to maintain, minimal nasal septal trauma/breakdown, low maintenance and cost effective
  - Neotech RAM Cannula®
Non-Invasive Positive Pressure Ventilation (NPPV)

**TYPES OF NPPV:**

- **Nasal CPAP** - Continuous positive airway pressure set on a ventilator with constant flow of gas.
- **Bubble CPAP** - Continuous positive airway pressure generated by submerging the expiratory limb in a water chamber that determines the CPAP level. It creates oscillatory chest vibration.
- **Infant Flow System** - A flow generator uses variable flow during exhalation while maintaining the desired CPAP. Better synchrony and less WOB among preterm infants compared to other CPAP device.
- **High Flow Nasal Cannula (HFNC)** - Positive pressure is generated at higher flow rate especially in infants. The level of CPAP depends on the flow rate, nasal prong size, and the infant. No built-in pop-off system.

**Non-Invasive Positive Pressure Ventilation (NPPV) (con’t.)**

- **SiPAP®** - Modified version of the Infant flow system with option for CPAP and Biphasic pressure setting along with sigh breath. The sigh breath are delivered above the CPAP level at the set frequency and duration. It has a transducer that monitors apnea and enables the user to set apnea breath.
- **Bi Level Positive Airway Pressure (BiPAP®)** - Provides two levels of pressure (Epap and Ipap). Has an option to provide backup rate. BiPAP Vision should be used on pediatric patients >20 kg (44 lbs).
- **Nasal Intermittent Mandatory Ventilation (NIMV)** - CPAP delivered by a CV with intermittent elevated pharyngeal pressures. The duration of the elevation in pressure depends on the set I-time and set PIP. Beneficial in preterm infants with frequent apneic episodes. Non-synchronous and continuous flow

**Ventilator Graphic Waveforms**

Three parameters are measured continuously on the ventilator as waveform:
- Volume
- Flow
- Pressure

These measured parameters (waveform) are plotted on graph.

- **Scalar Graph**: The measured parameter is always plotted on the Y axis and time on the X axis

- **Loop Graph**: The measured parameter are plotted on both the X and Y axis
Scalar Vs Loop

- Scalar Graph

Ventilator Flow Waveforms

- Sine wave: spontaneous breath, cpap
- Decelerating wave: mostly pressure breath, longer I Time
- Square wave: volume breath, constant flow

Ventilator Waveforms

LOOP GRAPH - Overdistension

- penguin or bird beak formation at the top of the loop
- Cause - high Vₜ or Pressure
- Fix - decrease Vₜ or Inspiratory pressure
- Remember VE will decrease

It is a good graph to monitor the constant change in RAW and compliance of the patient lung
Ventilator Waveforms
Loop graph - Leak
- Incomplete loop, the waveform never returns to baseline or zero
- Cause - Et tube cuff leak, leak around area of chest tube, BP fistula, loose circuit connection
- Fix - Check the inspiratory and expiratory circuit of the ventilator, replace the ruptured Et tube or insert a bigger size
Also an indication that the prior swelling or edema has decreased

Ventilator Waveforms
Loop graph - Obstruction
- Peaking of the loop (or a concave area) with a decreased flow rate, increased RAW
- Cause - secretions in the airway, bronchospasm, water in the tubing, plugged airway
- Fix - Suction the patient, bronchodilator therapy, empty the condensation in the ventilator circuit

Ventilator Waveforms
Loop graph - Compliance
- The farther the loop moves to the right and the more horizontal it is to the pressure axis the lower the compliance of the lung
- Cause - Patients with RDS, pulmonary edema, BPD
- Fix - Surfactant replacement therapy, optimum PEEP,
Ventilator Waveforms

Scalar graph - Auto PEEP
• The expiratory flow does not return to baseline before the beginning of the next breath
• **Cause** - Hyperventilation which decrease E time, increased RAW can lead to air trapping
• **Fix** - Increasing expiratory time, increasing the flow and increasing PEEP/MAP

References: